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Methods of Coloring Cements and Plasters

Ceramic Engineering

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**METHODS OF COLORING CEMENTS
AND PLASTERS**

BY

HOLLAND ROBERT BACHER

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

CERAMIC ENGINEERING

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Holland Robert Bacher

ENTITLED Methods of Coloring Cements and Plasters.

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science

in Ceramic Engineering

R S Still
Instructor in Charge

APPROVED:

R S Still

HEAD OF DEPARTMENT OF

Ceramics



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Methods of Coloring Cements and Plasters.

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Methods of Coloring Cements And Plasters.

I. Introduction.

1. Purpose of the investigation.

The materials for coloring cements and plasters in use at the present time are not permanent, being composed of organic dyes and compounds or inorganic oxides or salts, which bleach out when exposed to the weather or when acted upon by the free lime present in the cement. It is the purpose of this investigation to develop methods of producing permanently colored cements and plasters.

2. Scope of previous investigation.

No data could be found in the University of Illinois library on any investigation along this line. The only material bearing on the subject which could be found were a few extracts from United States and French patents,* and some data on cement coatings.

Information and samples were obtained from five companies manufacturing mortar colors and cement coatings. Few of these colors seem to occupy the field covered in this investigation.

* U. S. 1,110,129 June 16, 1914. Coloring cements by mixing chromates or lakes and a hydrocarbon like petroleum.

* U. S. 1,106,298 August 4, 1914. Mixing pigment with a rosin soap.

* French, 464,057 September 24, 1913. Coloring maolin with soluble salts of the metals and calcining.

* U. S. Bureau of Standards, Tech. Paper, NO. 3, study on cement coatings and materials.

3. Outline of present investigation.

In order to produce permanent colors, the available materials are limited to inorganic oxides and soluble salts of the metals, since organic dyes bleach, fade, or change in color due to the action of the weather and free lime present in the cement. The use to which the cements are put determines to a large extent the method of manipulation. The investigation was carried on with the purpose of producing, (1) a coloring material which could be mixed with Portland cement when used, for outside decorative work, such as coverings for residences and other types of buildings, (2) inside decorative work, such as hallways, lobbies, staircases, etc., the colored cement to be applied directly or moulded into tile or special shapes.

The methods of producing the coloring material for the first use are three, (1) using an inexpensive frit colored with metallic oxides, (2) a kaolin or similar aluminous base, soaked with the soluble salt of a metal and calcined, which was indicated by French Patent 464,057, (3) incorporating the coloring oxide directly into the raw white Portland cement. The first two methods would give colors which could be mixed with Portland cement when used, the third method would be ready for use, needing only to be mixed with the bonding material and water. None of the three methods seem to give very strong colors, but would be satisfactory for outside decorative work, such as building coatings where only a tint is desired.

For inside decorative work the third method might be used, the cement being mixed neat. The second method is to incorporate the coloring material in an Estrich plaster or setting set plaster

or raw gypsum with a soluble metallic salt and calcining to 1000 C.

All these methods were experimented with except that of incorporating the coloring oxide in the raw white Portland cement. The investigation then falls into two methods which will be taken up separately. They are, coloring material

1. Mixed with cement or plaster.

a. Frits.

b. Colored kaolin base.

2. Used directly as cement.

a. Colored Estrich plaster.

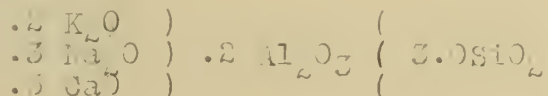
b. Colored Portland cement.

II. Experimental work.

Frits--

In order to cut down the gray color in an ordinary Portland cement and to act as a colorless sand in the final mixture, two to four parts of finely ground flint were added to the cement along with the frit. This does not cut down the tensile or compressive strength appreciably.

It was decided from knowledge of glazes and their frits, to make a frit of the following general empirical formula, and to substitute different coloring oxides in the RO in the frit, in order to test the coloring power of the powdered frit.



Cobalt oxide having a strong coloring action, was tried first,

The .5 CaO in the RO was replaced by .2 NaO according to the following empirical formula:

(One)

.2	K ₂ O	)	
.3	Na ₂ O	)	.2 Al ₂ O ₃ (3.0 SiO ₂
.2	CoO	)	
.3	CaO	)	

Batch Weights.

Potash feldspar	37.4
Sodium carbonate	10.4
Whiting	10.2
Flint	36.4
Cobalt oxide	5.6

The materials were thoroughly mixed and passed through a 40 mesh screen five or six times, and fused in a pot furnace. The fusion was extremely difficult as the mixture was highly viscous and refractory, requiring eighteen hours before the melt could be poured from the crucible. It was poured into cold water which broke up the mass into fine particles, these were ground in a ball mill to pass a 100 mesh sieve. After grinding and drying, three different mixtures using different percentages of the coloring powder, cement, and flint were made by mixing with water and allowing to set.

(Two) 1	Cement	20	by weight.
	Flint	60	"
	Frit	20	"
3	Cement	15	"
	Flint	45	"
	Frit	40	"
6	Cement	10	"
	Flint	30	"
	Frit	60	"

Frit (One) before grinding was an intensely deep blue, but after grinding the powder was much lighter in color. All three samples showed blue coloring, A being very light, B somewhat darker, and C the darkest. Although the percent increase was the same there was not as much difference in color between B and C as between B and A. However, none of these mixtures were satisfactory since the colors were too light. The mixtures were placed on wall tile and seemed to be very weak and friable. This was probably due to the water being absorbed too quickly by the porous wall tile so that the cement did not have enough **water** for its initial set.

Copper oxide being comparatively inexpensive and capable of producing green colors, was next tested. The same general empirical formula being employed except that B_2O_3 was introduced in order to render the frit more fusible and fluid.

(Three)

.2 H_2O	)		
.3 H_2O	)	.2 Al_2O_3	(3.0 SiO_2
.35 CaO	)	.6 B_2O_3	(
.12 SnO	)		

Batch Weights.

Potash feldspar	25.1
Borax	30.1
Whiting	5.9
Copper oxide	2.5
Flint	23.4

This gave a fair green before grinding but the powder resulting therefrom was almost white. In order to obtain a darker green, NO.(Three) was made in which the CaO was raised from .12 to .3 Mols., and the B_2O_3 was reduced from .6 to .4 Mols. The B_2O_3 was lowered to reduce the cost since the increased CaO would lower the fusion temperature.

(Four) .2 K_2O)
 .3 Na_2O) .2 Al_2O_3 (
 .3 CuO) .4 B_2O_3 (3.0 SiO_2
 .2 CaO)

Batch Weights.

Potash Feldspar	31.8
Borax	21.4
Sodium carbonate	3.0
Whiting	5.7
Flint	31.3

Two mixtures were made up as follows, and applied as before:

(Four) A	Cement	50
	Flint	40
	Frit	40
(Four) B	Cement	50
	Frit	50

(Frit Four) was a fair green after grinding, but the mixtures gave a gray green which was in no way satisfactory as to color.

In the next frit the CaO was increased by .3 Mols. making a total of .6 Mols. in the empirical formula and the B_2O_3 was entirely eliminated as it was not necessary with such a high content of CuO . This frit was

(Five) .1 K_2O)
 .2 Na_2O) .2 Al_2O_3 (3.0 SiO_2
 .5 CuO)
 .1 CaO)

While in frit (Five) the copper was just doubled, there was not an appreciable difference in the intensity of the color.

For this reason the mixtures were not made up for this frit as they were for the last series.

Results and conclusions on frits:

From these experiments it was shown that a frit is impracticable for the following reasons:

1. A frit being similar to a glass loses its ^{apparent} color on grinding for as the particles become finer more light is allowed to be reflected from them, which gives a weaker color sensation. For this reason a strong color can not be obtained no matter how much coloring oxide is used in the frit.

2. Any color so made, no matter how intense, when mixed with a gray Portland cement is bound to decrease in intensity owing to a dilution or modification.

3. To get a desirable color it would be necessary to use such high percentages of the frit that it would become too expensive.

Colored kaolin base.--

Kaolin is much used in the preparation of underglaze colors, and the process used in this investigation is practically the same method as is used in the preparation of these colors.

The first color tried was as follows:

North Carolina kaolin, 90 grams.
Cobalt sulphate, 10 grams.

The cobalt sulphate was taken into solution with water and mixed with the kaolin, so that it was in a slip condition. This was dried at 110 C. and divided into two portions. The first portion was calcined in a Hoskins electric furnace to 950 C., and the second in a gas pot furnace to 1350 C.

Results:

The strength of the color is increased with increase in temperature. The color increases the closer vitrification is approached, and reaches its maximum intensity when fusion takes place. The portion calcined at 800 C. was about the same color as that of the cobalt frit (One). That at 1350 C. was considerably stronger. Both were more purple in color than the cobalt frit.

Conclusions:

As these colors were so little better than the frits and as such a high percentage of the coloring salt was used, it was evident that a kaolin base would have the same disadvantage as a frit. That is, it would be just as expensive and would give no improvement in the final color when mixed with a Portland cement or plaster.

There remains now to investigate the two methods for producing a colored cement which could be used directly for inside work, namely (1) incorporating a coloring oxide in a raw white Portland cement batch, and (2) soaking raw gypsum or set plaster with a soluble metallic salt, and calcining, producing a colored Estrich plaster. Only the latter was developed in this investigation.

Colored Estrich plaster.

Estrich plaster is an anhydrous gypsum, burned between 900 C. and 1300 C. It may be made from raw gypsum, plaster of paris, set plaster, and plaster burned to 500 C. It forms a slow setting, hard, dense cement with properties similar to Portland cement. The advantage in coloring an Estrich plaster is that it can be done easily and cheaply and gives an excellent cement. The colored cement could then be used directly either by applying to the surface where it is to be used or by molding into tile.

2

In this way the colors would not be modified by the addition of a gray Portland cement, sand or flint as in the case of frits and colored kaolin base. Then too, if simply a tint was desired, this colored Estrich plaster could be used the same as a frit or colored kaolin base in a Portland cement mixture, making it more universal.

In this investigation the soluble salts were added to (1) raw gypsum, (2) plaster of paris, (3) set plaster, (4) plaster burned to 500 C.

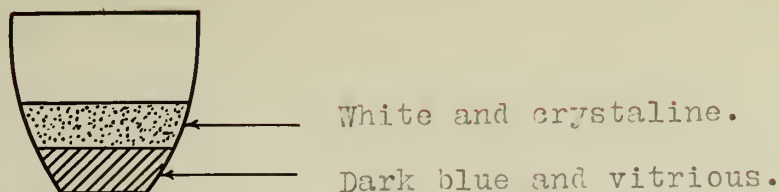
Series (Six)

(Six) A	Cobalt sulphate	10
	Set plaster	90
B	Cobalt sulphate	10
	Plaster of p. to 500 C.	90

The cobalt was made into a water solution and mixed with the plaster. This was then dried at 110 C. in an electric oven for five hours. Both samples were burned to 850 C. in a Costlin electric furnace in small porcelain crucibles. This was the highest temperature that could be reached, which was not sufficient to develop the color. (Six) A was powdery and had become slightly blue, (Six) B was bluish gray and had clinkered. In order to obtain 1300 C. or 1400 C., these samples were again fired in the gas Pot furnace. It was supposed that no higher temperature could be reached in this furnace, but from the results it must have exceeded 1400 C. considerably.

Results:

(Six) A had fused forming two compounds which separated as shown in the following sketch:



(Six) was much the same as before. It was harder showing very little color change except where it had fused on the bottom of the crucible to a deep blue.

Conclusions:

It is evident from these results that too high a temperature was reached to obtain extrich plaster. The cause for the fusion in (Six) A was due to the CaSO_4 partly dissociating into CaO formed a eutectic mixture of the two compounds which fused at a lower temperature than that required to fuse pure CaO .

Series (Seven)

In order to be certain of the temperature reached this series was burned in a muffle gas fired furnace using a pyrometer.

Unset plaster of paris and set plaster were used in this series. The samples were mixed in each case with a water solution of the sulphates of the metals. The ratios were calculated so that 10 percent by weight of the metal was used with 10 percent Ca . Later this will be seen to be an unsatisfactory ratio. The samples were made as follows:

(Seven) 11.	Set plaster	15 grams.
	Cobalt sulphate	1.5 "
12.	Unset plaster	15.5 "
	Cobalt sulphate	1.5 "
31.	Set plaster	13.0 "
	Chromium sulphate	15.2 "
32.	Unset plaster	15.5 "
	Chromium sulphate	15.5 "

C1. Set plaster	13.0	Grams
Copper sulphate	0.2	"
D1. Unset plaster	13.0	"
Copper sulphate	0.2	"
D1. Set plaster	13.0	"
Manganous sulphate	10.0	"
D1. Unset plaster	13.0	"
Manganous sulphate	10.0	"

These samples were dried in the electric oven at 110 C. for five hours, ground, mixed, and placed in fire clay assay crucibles. They were all burned to 1150 C. in eight hours and cooled slowly. The samples were then ground to pass 100 mesh. Part of the ground material was mixed with water and made into pattis and allowed to stand. The remainder was made into pattis using a 10 percent alum solution instead of water. These were placed on a glass plate and kept in a moist atmosphere by setting the plate in a sealed jar partly filled with water.

Results:

The chromium colors were both a good green and the manganese a good chocolate brown. The copper and cobalt colors were a dirty blue.

Of the samples mixed with water, only those in which the set plaster had been used showed evidence of setting at the end of one day. All those in series (Seven), mixed with the alum solution set in three days and were quite hard. The hardness increased after they had remained out of the wet and three or four days.

Conclusions:

From the results of this series, it is seen that the cement may be made satisfactorily from either of the two forms of plaster, using an alum solution to make them set. That all the colors were not good is not evident. Each salt may require its own burning

temperature. This experiment shows that good colors may be obtained by this method of coloring Estrich plaster. It also shows that alum added in solution, when the cement is mixed, improves the setting qualities. It now remains to develop more colors by this method and make physical tests upon the plaster.

Series (Eight):

In order to make physical tests for crushing and tensile strength, a large amount of the chrome green was made as follows;

Unset plaster	206 Gr.
Chromium sulphate	71.4 "

The right amount of water was added to make a stiff paste and the mixture cast into moulds. The dry briquettes were burned to 1000 C. in the gas fired muffle furnace for 6 hours. The plaster was burned in the briquette form to determine whether they would give as good a color as when in the powdered form. After burning they were ground mixed with a 5% alum solution, cast into tensile test moulds, and allowed to set. After 7 days the briquettes were tested for tensile strength and porosity.

Results:

It was noted that the presence of the chromium sulphate retarded the setting of the plaster of paris. The specimens received an initial set in 10 hours. After seven days the dry briquettes, (6) showed a tensile strength as follows;

Number	Lbs. per sq. in. at rupture.
1	625
2	605
3	635
4	641
5	635
6	605
Average	<u>624.3</u>

The average tensile strength on three specimens in the dry condition after a 21 day set was 672 lbs. per sq. in. The average percent porosity on two specimens was 1.045 %.

Conclusions;

1. A soluble metallic salt may act as a retarder in the setting of plaster of paris.

2. The tensile strength of Estrich plaster containing a metallic salt in 7 and 21 days, as compared to the averages of the dry Portland cement given in Tech. Paper No. 3 of the Bureau of Standards, is about the same.

Series (Nine)

This series was made so as to further develop the colors produced in series (Seven). In order to develop a blue color with a cobalt salt which is known to be best developed in fusion with ZnO or Al_2O_3 , the following series was made.

(Nine) A. Set plaster	95 %
Alum	5 %
BB. Set plaster	90 %
$Al_2O_3 \cdot 3H_2O$	10 %

Low Al_2O_3 was used in the dry condition to see if it was practical to dry grind it with the plaster. The samples were dry ground in a ball mill to pass 100 mesh. Difficulty was experienced in grinding due to the water in the plaster. For this reason the Al_2O_3 content was increased by adding alum in a water solution. 5 grs. alum in solution was added to the soluble salt solution and both mixed with (Nine) AA and BB as follows;

(Nine) A.	(Nine) AA	90 Gr.
	Set plaster	5 "
	Alum (in solution)	5 "

(Nine)A.	(Nine)BB	50 Gr.
	Copper sulphate	5 "
	Alum(in solution)	5 "

The alum was added to the copper sulphate to determine whether or not alum would act in this case as it does with cobalt sulphate in developing the color. In this series and those following, the amount of water was estimated and added, so that, a thick paste was formed which dried very quickly and evenly. The samples were also ground before burning. To determine the effect of zinc sulphate in developing the color with cobalt sulphate, the following mixture was made.

(Nine)D.	Set plaster	50 Gr.
	Cobalt sulphate	5 "
	Zinc sulphate	5 "

The next point was to determine whether or not a chloride could be used as well for this purpose as the sulphate, in fact the nitrate and potassium salts should also be tested. In doing this iron chloride, uranium nitrate, potassium dichromate and potassium permanganate were used, thereby introducing two untried metals, iron and uranium. These were made as follows;

(Nine)C.	(Nine)BB	50 Gr.
	Ferrous sulphate	10 "
(Nine)E.	Set plaster	50 Gr.
	Uranium nitrate	10 "
(Nine)F.	Set plaster	50 Gr.
	Potassium dichromate	10 "
(Nine)G.	Set plaster	50 Gr.
	Potassium permanganate	10 "

The ground samples were placed in fire clay assay crucibles and burned to 1000 C. in the gas fired muffle furnace, a lower temperature being more economical. 1000 C. was reached in 6 hours and held for 2 hours. The samples were all reground, made into patts with a 5 % Alum solution, and set as in series (Seven). They received an

Initial set in from 40 to 50 minutes.

Results:

The results of this series were excellent as the colors were extremely bright and clear, (Cu and Co in excepted) as shown

in the following table:

	Color	Condition of sample.
(Nine) A	green blue	soft
B	gray green	hard
C	pink red	soft
D	gray blue	hard
E	bright yellow	soft
F	bright green	soft
G	Malberry purple	soft

Conclusions:

The addition of Al_2O_3 to cobalt sulphate gave a decidedly greenish blue while the zinc and cobalt did not give a good color as it was a dirty grayish green. (Nine) A shows that the presence of Al_2O_3 tends to give a blue. A different ratio of Al_2O_3 to Co might produce a better blue. The Al_2O_3 did not help the copper color out there is no data even on glazes to show that this might be the case.

This series also shows that a chloride, nitrate or potassium salt gives good colors. The dichromate (Nine) F gave a more yellow green than the chromium sulphate. This does not appear, however, until after setting.

Uranium (Nine) E, gave almost a primary yellow. The iron was a good color as well as the permanganate.

From this series it is evident that most any shade may be developed but the percentage of the soluble salts is too high from a commercial standpoint. In another series these percentages will be cut down considerably to see if good colors may still be obtained.

Before running this series, however, further experiments were carried on by mixing a number of different colors together to determine their blending qualities.

(Nine) H	(Nine) E	50%
	(Nine) C	50%

This gave a very good buff color which had all the properties of the original sample. Another mixture was made as follows:

(Nine) I	(Nine) C	40%
	(Nine) D	40%
	(Nine) C	20%

This sample gave a light chocolate brown with the same properties of the original samples.

Equal portions of (Nine) C and (Nine) E were mixed up separately and then intermixed so as to give a chocolate and green marbled effect.

Results:

These experiments would indicate that most any shade or tint can be produced by mixing varying proportions of the original colors.

Series (Ten)

From a commercial standpoint it would be necessary to use much less than 10 percent of the soluble salt. To determine just how little could be used to produce a sufficiently strong color the following series was made using between one and two percent of the salts.

In the first member the ratio of Al_2O_3 to $CoSO_4$ was increased to 1 to 3, to see if the blue could be further improved over (Nine) A as follows:

(Ten) A	Set plaster	100%
	Cobalt sulphate	2
	Alm	6

This and all the succeeding members were prepared the same as in series (Nine) throughout the whole operation except that they were burned in an open fire, oil fired kiln to cone 05 in eighteen hours which nearer approaches commercial conditions than any other previous burn.

As in (Nine) D, zinc chloride was again tried but Li_2O_2 was also added and the cobalt sulphate cut down as follows:

(Ten) B	Set plaster	99.5
	Cobalt sulphate	2
	Alum	4
	Zinc chloride	4

The next three members corresponded to (Nine) C, (Nine) D and (Seven) B with the percentages of the soluble salts reduced.

The weights used were as follows:

(Ten) C	Set plaster	99.5
	Ferrous sulphate	1
(Ten) D	Set plaster	99
	Uranium nitrate	1
(Ten) E	Set plaster	99
	Chromium sulphate	1

The next member was an attempt to produce chrome-tin pink. No data being available as to the percentage to be used, the following was tried:

(Ten) F	Set plaster	98.5
	Chromium	2
	Stannous chloride	2

The last member corresponds to (Nine) C with a smaller percentage of KMnO_4 as follows:

(Ten) G	Set plaster	98.5
	Potassium permanganate	2

Results:

The results of this series showed as was supposed, that a considerable excess of the soluble salt had been used in the

previous series. The following table shows the colors obtained:

NO	Color	Condition of sample.
(Ten) A	Light blue	hard
B	Olive green	hard
C	Brick red	medium
D	Lemon yellow	soft
E	Pale yellow green	medium
F	Yellow green	hard
G	Light chocolate brown	hard

In this series the blue was obtained with cobalt sulfate and Al_2O_3 in (Ten) A which was a decided blue.

(Ten) B was a decided olive green. Although a blue color was sought for in this member it is not surprising that a green was obtained for zinc minerals in the presence of cobalt nitrate give green before the blow pipe on charcoal.

(Ten) C gave a good brick red, as good as that of series (Nine).

(Ten) D could not be used for a good green although it was a good light buff color.

(Ten) E-- This being a yellowish green, it is evident that the correct ratio for a pink was not used. In several spots, however, there were indications of a pink color and one small mass of grains was a decided pink.

(Ten) F was an excellent lemon yellow and almost as strong as (Nine) E.

Conclusions:

From this series some significant facts are brought out.

1. Good colors can be produced with about 1 to 5 percent soluble salt.

2. A good blue can be obtained with cobalt sulfate and Al_2O_3 in the proper ratio.

3. It seems possible to produce a chrome-tin pink if the proper ratio of chromium to tin can be determined.

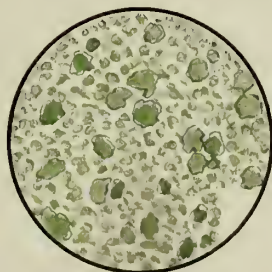
4. About 2 percent is the limit at which a good green can be obtained with chromium sulphate.

5. Lime does not improve the result color, but it can be used to produce a green color.

In order to observe what action takes place when these cements are in the process of setting, a microscopic examination was made.

Microscopic examination:

An attempt was made to study the setting of the cement under the microscope, but the cement could not be made thin enough to allow the light to pass through the slide and yet thick enough to set. However, a thin slip of the chrome-green cement was made and examined under 10 millimeters. This is shown in the following sketch of the slide:



This shows that the grains vary greatly in size and are decidedly rounded. It also shows that the color has penetrated all the grains from the most minute to the largest.

Before summarizing this investigation some consideration of the commercial manufacture will be discussed.

III. Commercial Considerations.

From the experimental data secured in this investigation some idea of the manufacturing side of the problem may be obtained.

Only the manufacture of the colored plastic plaster will be considered, as the use of frits and colored kaolin base was proved to be impractical. A brief outline only can be given here.

Raw materials.

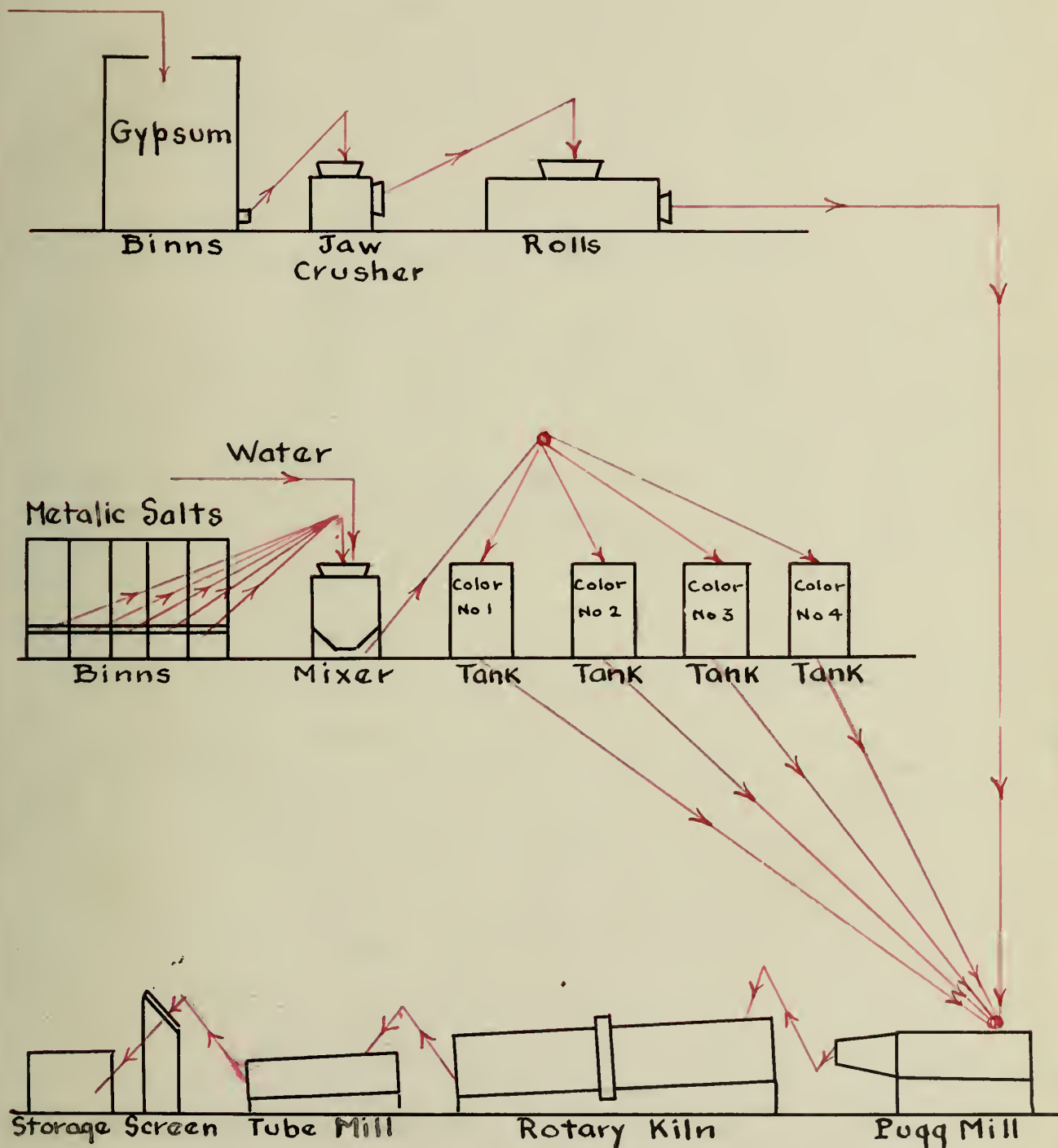
Set plaster or raw gypsum would be the cheapest form to use. Set plaster could be obtained as a waste product in the form of old molds, casts, etc., from the terra cotta and similar industries. In most cases this would be contaminated by clay impurities from molding but if sufficient amount of relatively pure material could be obtained it would be relatively cheap. Raw gypsum would probably be the cheapest form and is widely distributed in extensive deposits so that the plant could be located in the vicinity of a deposit. The coloring metallic salts could be obtained from dealers or if the size of the plant warranted it, made at the plant.

Operation.

A continuous process of manufacture is generally the most efficient so that system will be discussed. Of course other systems could be used, but with the data at hand the one here devised seems quite practical. Plate I, shows the various stages in the process. The raw plaster or gypsum is fed into a jaw crusher for rough grinding and passes from there through rolls where it can be ground fine enough for grinding and mixing. From the rolls it is carried to a pug mill. Here the coloring salt solution is added from tanks above. After being thoroughly mixed it is forced by an auger machine directly into the kiln.

The kiln is rotary, of the Portland cement type, the drying taking place at the upper end and the burning beginning as the material moves down the length of the kiln.

PLATE 1



The calcined would not be hard and could be crushed to the fine condition directly in a tube mill. After screening it is ready for packing and shipment or use at the plant.

If the plant made the cement into tile it would require a molding department with suitable machinery for the purpose. The tile could probably be made by the "stiff mud" process.

Cost of manufacture.

The cost of manufacturing is almost impossible to estimate as it would be dependent upon, the size of the plant, location, etc. The cost of the product would vary with the color made. For example, iron red would be much cheaper than cobalt blue or chrome green on account of the difference of the soluble salt. However, from Portland cement cost data, and from the current prices of raw materials, it is fair to estimate that colored Estrich plaster may be manufactured profitably.

IV. Summary and conclusion.

1. The use of frits and colored kaolin alone to produce a colored cement is not satisfactory unless they are mixed with a white Portland cement so that the mixture contains about 50 percent of the frit or kaolin, which would make it too expensive.

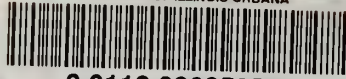
2. Incorporating the coloring oxide directly with the raw Portland cement batch, the materials of which would otherwise give a white cement, has not been studied in this investigation.

3. A strong, hard, smooth cement with a wide range of good colors can be produced by soaking raw gypsum, set or unset plaster of paris, with a soluble metallic salt and calcining to 1000 °.





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